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Using scenario analyses to address the future of food

Tim G Benton

School of Biology, University of Leeds, Leeds, LS2 9JT, UK; Energy, Environment and Resources Department, The Royal Institute of International Affairs, Chatham House, 10 St James's Square, London, SW1Y 4LE, UK

Abstract

The food system was developed around a set of policy drivers to make food cheaper and more available, these included promoting agricultural productivity and global trade to increase the availability of food. However, as has been recognised by a plethora of recent papers and reports, these factors have also led to a food system that is unsustainable through its impacts on human health (particularly the growing obesity epidemic) and the environment (e.g. as a major driver of climate change). The world is changing at an unprecedented rate, and the food system is becoming increasingly 'just in time', spatially extended, and dependent on more facilitating sectors (water, land, transport, finance, cyber, etc.). This produces a degree of systemic fragility that drivers (like demand) can interact with events (e.g. a climate impact) to create the opportunity for large-scale shifts in the way the world works. Given the unsustainability of the food system, and the uncertainty of how it may evolve, scenario analysis can be a useful tool for imagining plausible futures as an aid to unlocking 'business as unusual' thinking. Summarising a number of recent processes, I describe scenarios of countries' food systems shaped by changing patterns of trade and changing dietary patterns.

Keywords: food security, food system, outsourced costs, sustainable, trade

Correspondence: t.g.benton@leeds.ac.uk; tbenton@chathamhouse.org

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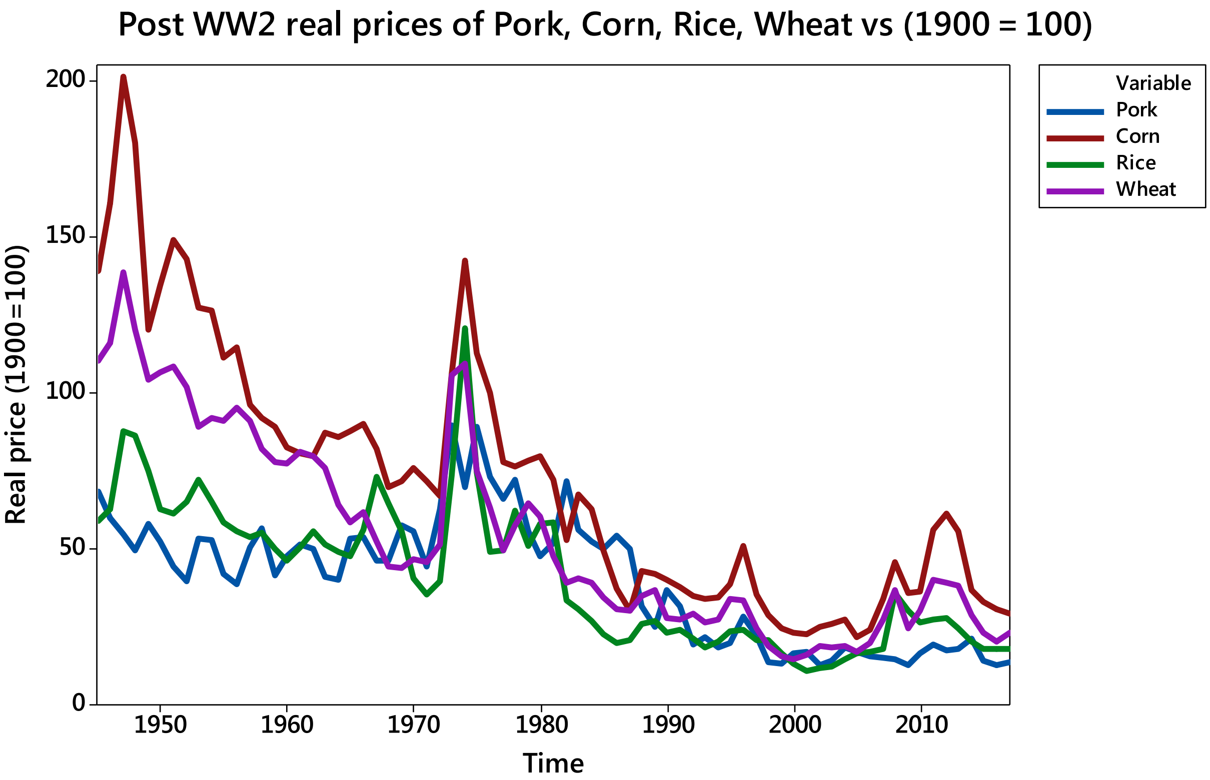
1. A brief history of the food system

In many ways, the development of both local and global food systems since the end of World War 2 has been a success. Investments in agricultural research and innovation have underpinned rapid productivity growth and, in concert with both the development of global and liberalised trade, and the competitive pressures it creates, have stimulated the adoption of intensive and large-scale agriculture across much of the world. Increasingly large-scale, intensive and productive agriculture has been the engine that has made food more available, and, on average cheaper decade by decade (Figure 1).



The prices are indexed to 1900 = 100, and are part of a longer series. The sharp spike in the 1970s represents the global oil price crisis, but against that up to the first decade of the 21st century there have been global long-term declines on average, such that commodities in the first decade of this century were ~20–30% of the price relative to the first decade post-war. Data available at: http://www.sfu.ca/~djacks/data/boombust/index.html and come from Jacks 'From Boom to Bust: A Typology of Real Commodity Prices in the Long Run.' NBER Working Paper 18874.

Figure 1: Real food prices since the World War 2 for four agricultural commodities

Following the food prices spikes at the end of the first decade of the 21st century, the productivity-driven, 'cheaper food paradigm', were reinvigorated through projections of demand for food (based on historical trends) suggesting a 70–100% demand increase by 2050 (Tilman et al., 2011; Alexandratos and Bruinsma, 2012; Hunter et al., 2017). This, coupled with recognition of the 'global storm' of demand growth and environmental constraints (from water, land and climate change), led to the 'sustainable intensification' debate: how to meet demand by raising the output per unit area (i.e. agricultural intensification) but minimising environmental impacts (i.e. increasing outputs sustainably) (Baulcombe et al., 2009; Garnett et al., 2013; Benton, 2016).

However, in recent years, there has emerged a growing recognition that 'the cheaper food paradigm' has not simply provided the social good that is typically thought to arise from cheaper food, but is increasingly creating social costs as 'externalities' arising from the production and consumption of food (Benton and Bailey, 2019). These externalities occur under the headings of health and environment.

Environmental externalities. Incentives based on production, global competition based on price, and long supply chains reducing transparency encourage the outsourcing of significant costs on the environment, including on soils (Amundson et al., 2015), biodiversity (Newbold et al., 2016), water (Liu et al., 2012; Dalin et al., 2017) and climate, in which agrifood emits as much as 30% of global greenhouse gases (Bajželj et al., 2013) and air quality (for example, a study in the USA suggested that local health costs can be about half the value of production; Paulot and Jacob, 2014). On average, each global consumer used 284 g of pesticide active ingredient in 2015 (data from FAOSTAT), 9 g of antimicrobials in 2010 (Van Boeckel et al., 2015) and 15 kg of nitrogen fertiliser (Davis et al., 2016).

Furthermore, as prices have been driven down by production growth and global competition, the economic incentive to avoid food waste has declined (Benton and Bailey, 2019): as productivity increases, waste increases faster, creating further pressure on the environment (from unnecessary production, and disposal of the waste, plus its packaging). There is increasing evidence that tackling climate change not only requires agricultural mitigation, through adopting 'climate smart agriculture' but also a fundamental change in the demand side of the food system (Bajželj et al., 2014; Springmann et al., 2018). This is particularly significant with respect to climate change, and the impetus of the Paris climate agreement, effectively codifying the level of 'safe' climate change to well below 2°C (IPCC, 2018).

Health system externalities. Some of the focus of the productivity agenda has been motivated by reducing global undernutrition, and, to some extent, this has been successful with a decreasing prevalence of underweight and stunting (NCD-RisC, 2016a). The flipside, however, is that decreasing prices and increasing availability of a small handful of crops underpin a globally increasingly standardised diet, rich in calories but often lacking nutrition (Khoury et al., 2014). As a result, global malnutrition 'in all its forms' is increasing (NCD-RisC, 2016a) due to the increasing prevalence of overweight and obesity, which has overtaken the global prevalence of underweight (NCD-RisC, 2016a). Non-communicable diseases associated with an excess of calories (Wagner and Brath, 2012), include diabetes (NCD-RisC, 2016b), dementia (Hugenschmidt, 2016), cardiovascular disease and several cancers. Dietary-related ill-health is now recognised as the prime global determinant of mortality (Initiatives, 2018; Stanaway et al., 2018).

Estimates of the total healthcare costs of malnutrition are patchy, but the FAO suggested in 2013 that healthcare costs associated with inadequate nutrition might exceed 5% GDP.[1] This may be an underestimate as, in the USA, the economic cost of diabetes, a disease strongly associated with obesity and affecting ~ 23 million Americans, is estimated at US$327 billion in 2017, with direct healthcare costs of US$9,600 per person (Association, 2018). By 2025, it is estimated that, globally, there will be over 700 million people with diabetes, over 30 times the number in the USA (NCD-RisC, 2016b). Even if a global average cost of diabetes per capita was a quarter of that in the USA, the total economic cost of diabetes would be approximately the same as global agricultural GDP (3.79%[2] in 2015). Given our current food system, malnutrition is both increasing, and increasingly expensive economically (Swinburn et al., 2019).

The recognition of the magnitude of environmental and health impacts 'the global syndemic of malnourishment and climate change' (Swinburn et al., 2019) gives a strong argument, based on the concept of planetary health, for a systemic transformation of the food system (Swinburn et al., 2019; Willett et al., 2019).

1.1. Vicious circles

The focus on agricultural productivity drives a set of inter-locking vicious circles (Benton and Bailey, 2019). The more we produce, the cheaper food becomes, and the more it comes from fewer crops supplying excessive calories: the more our diets become both obesogenic and standardised (Khoury et al., 2014). Cheaper food requires intensive agriculture, at scale, undermining natural capital and increasing resource competition. At the same time, it drives climate change through incentivising more livestock production, via production of cheaper feed, and land expansion, to fulfil growing demand. This further intensifies pressure on land, as it increases the need for land for climate mitigation through negative emissions. The end result is more degradation, more waste and more ill-health from overweight and obesity.

[1] Food and Agriculture Organization of the United Nations. State of Food and Agriculture 2013: Food systems for better nutrition. 2013 Rome, Italy.

[2] https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

1.2. Transforming the food system

Transforming the food system to deliver healthy and sustainable diets might be necessary to balance health, food and climate security and tackle the syndemics (Swinburn et al., 2019). Furthermore, the UN's 17 sustainable development goals (the SDGs) are challenging not because each of the goals is challenging, but because they are inter-dependent: tackling the 'Zero Hunger' challenge by producing more and cheaper food is likely to further undermine other goals (such as Goal 6, access to clean water, Goals 15 and 14, life on land and in water, and Goal 13, climate action.

Looking ahead to a population that is probably 9.7 billion in 2050, and 11 billion towards the end of the century (Gerland et al., 2014), there are very significant challenges on the horizon. If the current food system is reducing human and planetary health, doing the same thing more intensively is not sustainable. In fact, there is growing recognition that a systemic transformation of the food system is required (Willett et al., 2019), and that 'business as usual is not an option'. This recognition comes from the business community (Forum, 2018b), academic academies (Partnership, 2018), and the IPCC (2018), as well as many environmental and civil society institutions.

If, in the long term, business as usual is not an option, what forces may cause it to change?

2. A changing and challenging world

The world is changing increasingly fast from many different outlooks: social, economic, technical, environmental (Steffen et al., 2015). We have a globally growing population, with more mobile, more connected, more wealthy people and with greater inequality between the rich and poor, collectively demanding more resources (e.g. food, water, energy, goods). At the same time as the planet is under pressure from demand growth, its ability to buffer the environmental footprint of demand (e.g. emissions of greenhouse gases and other pollutants, soil degradation, biodiversity loss, waste, including plastic) is finite, and, arguably, we are now close to the 'planetary boundaries' (Rockström et al., 2009) beyond which Earth-system processes may degrade. Climate change is having noticeable effects as extreme weather becomes more common, impacting people through floods and droughts, affecting food supply and infrastructure.

At the start of the 21st century's first decade, the future looked very different from how it looks today. International rule-based cooperation had led to unprecedented stability and global integration, such that there was discussion of the potential of a post-nation state world (Sassen, 2002; Ehrkamp and Leitner, 2006). Growing radicalism, terror, the threat of terror and a growing inward-looking nationalism, partly driven by inequality growth and immigration, has now led us to a very different world from that at the turn of the century. If the last decade's developments are not a 'blip', we may radically diverge from the direction of travel since the World War 2 and the rise of the Bretton Woods' international architecture of cooperation, which underpinned globalisation. So, not only is the world changing fast, but the changes are increasingly challenging from environmental and geopolitical outlooks, to the point of, for example, climate change being an existential threat to the way society works in the long term. Within this 'changing and challenging world' context, some societal issues are becoming both more urgent (as time runs out to drive positive change) and more significant (as the scale of the challenges grows). These factors set the context for the future of food systems in the decades ahead.

2.1. The role of events in shaping the future

The large-scale trends, associated with driving appreciable societal change, whether through attitudinal, behavioural, economic or environmental mechanisms, are colloquially known as 'megatrends'. The trends identified as 'mega' depend to an extent on the context and institution describing them. For example, *PwC* describe five: urbanisation, climate change and resource security, shifting global power, demographic and social change, and technology,[3] whereas the UN adds poverty and inequality, shocks and crises (as well as development finance) to their list.[4]

The future is not simply shaped by drivers, like population growth or climate change, unfolding in a gradual way. 'Events happen' as the saying goes, and sometimes these events are highly impactful. This can arise for two reasons: they are a rare, but high impact event – unexpected and perhaps

[3] https://www.pwc.co.uk/issues/megatrends.html

[4] http://www.undp.org/content/undp/en/home/librarypage/sustainable-development-goals/global-trends--challenges-and-opportunities-in-the-implementatio.html

unprecedented. Such events have been termed 'black swans'. Or they can arise by an event unleashing a sequence of consequences, through the interaction of the megatrends, and the pressure they put on the system, that collectively reshape the way the world works (e.g. think of 9/11, the Global Financial Crisis, Syria/Libya, migration into the EU).

Humans tend to be linear thinkers, and often implicitly assume that the way the world works today will only marginally and incrementally change into the future. This predisposes us to think in terms of 'business as usual' scenarios. But the world is highly non-linear, stochastic and complex: this can create the fertile ground for systemic shocks to deconstruct 'business as usual'. Such shocks may be disruptive, but they also provide opportunities to reconfigure systems that are often 'locked in' and so resilient to change.

Systemic shocks can occur through the interaction of drivers, trends and events (as highlighted each year by the World Economic Forum's *Global Risk* Report) (Forum, 2018a). Food security – a secure supply of food to feed a country – arises as a combination of local supply and global trade. The latter has become more significant with growing globalisation, creating a dependency on trade for any country's food supply. Furthermore, agriculture depends on water, land, supply of chemicals and energy, and increasingly cyber (satellite navigation in precision agriculture and transport networks); and in these days, especially in high-income countries, food systems are increasingly 'just in time'. So food security requires a range of sectors, infrastructure, complex logistics, finance, and so on across the world to work in concert to supply a nation's requirements. This codependency across sectors, and just-in-time supply, means that a shock (a climate change impact, a change in energy policy, a geopolitical disruption) can propagate through the system creating worldwide impacts on food security (Homer-Dixon et al., 2015; Challinor et al., 2018). Furthermore, the codependency (across space and sectors) means that there are a very large combination of potential shocks, places they could happen and pathways they could propagate through to create a high impact.

Quoting from United States *Global Strategic Trends 2035*[5] (p. 65):

> 'Examining the trends…makes vivid that the world will become more volatile in the years ahead. States, institutions, and societies will be under pressure from above and below the level of the nation state to adapt to systemic challenges and to act sooner rather than later. From above, climate change, technology standards and protocols, and transnational terrorism will require multilateral cooperation. From below, the inability of government to meet the expectations of their citizens, inequality, and identity politics will increase the risk of instability. Responding effectively to these challenges will require not only sufficient resources and capacity but also political will. Moreover, the extent of these challenges might overwhelm the capacity of individual states and international institutions to resolve problems on their own, suggesting a greater role for a wide range of public and private actors.'

3. Plausible food scenarios: strategising under uncertainty

The speed of change – population growth, social attitudes, technological, environmental – is faster than it has ever been (Steffen et al., 2015; Schwab, 2016). Human systems are increasingly interconnected (across sectors and space) (Liu et al., 2015), so that significant social determinants (like food) in any one country depend on access to land, water, energy, finance, transport, IT and satellites and more at multiple spatial scales. This means events far away, in sectors unrelated to food, have the potential to impact food availability locally (Homer-Dixon et al., 2015; Puma et al., 2015; Challinor et al., 2018). This complex system, rapidly changing from within, as social attitudes change and technology is developed and demand evolves, is increasingly fragile to systematic shocks, particularly from increasingly unprecedented climate. This means its future is far from predictable. This unpredictability is summed up with the TUNA acronym: Turbulent, Uncertain, Novel, Ambiguous (Ramírez and Wilkinson, 2016). The future is turbulent because of its systemic fragility and non-linearity, meaning events can lead to escalating impacts (Homer-Dixon et al., 2015); uncertain because these are often highly unpredictable; novel because technological, social and environmental changes create unprecedented situations; and ambiguous because every problem or solution is wicked, with both 'winners' and 'losers'.

[5] https://www.dni.gov/files/documents/nic/GT-Full-Report.pdf

Given the conclusion from Section 1 is that 'business as usual' is not an option, and from Section 2 that fragile complex systems may increasingly be subject to shocks that unshackle 'business as usual lock-in' and therefore provide opportunities for rapid change, what might the future look like?

Scenarios are a route to aid decision making under uncertainty (Courtney et al., 1997), when past trends cannot necessarily be extrapolated into the future with confidence, and where the future is likely to be shaped by drivers or events which may plausibly lead to very different outcomes. Some scenarios analyses have been published recently for food systems (see compilation at https://www.foresight4food.net/). While scenarios may take a variety of forms, a common approach is to identify the two most significant drivers which will be shape the future, but about which there is great uncertainty about what form they will take. A recent report taking this approach was published by the World Economic Forum in 2017 (Forum, 2017). The WEF's two key axes were chosen because they are inherently unknown in how they may develop, but are very strong determinants of the way local food systems may be shaped.

The two dominant factors were:

1) Dietary shifts: away from food systems with their high outsourced costs on health and environment (Swinburn et al., 2019) to food systems that provide more healthy diets in a sustainable way. The drivers for such shifts include climate mitigation, healthcare costs of malnutrition and associated non-communicable diseases (for both personal and health economic reasons), impacts on health from production (the rise of antimicrobial resistance from intensive livestock production, urban air quality being impacted by intensive agriculture and volatilisation of nitrogenous fertiliser) and environmental sustainability (e.g. reduction in plastic waste, reduction in food waste, societal demand for fewer pesticides to be used in agriculture). Other processes that consider the shift to healthy and/or sustainable diets include Agrimonde,[6] the EU Joint Research Centre (JRC) food systems' foresight study[7] and the Shared Socioeconomic Pathway 1 for the IPCC (O'Neill et al., 2017). While 'healthy diets' are not exactly synonymous with 'sustainable diets' there is a significant overlap between the two as: (a) healthier diets have fewer calories through reduced average consumption, and (b) healthier diets are more based on plant-produced foods, and less reliant on meat, with its high environmental footprint (Aleksandrowicz et al., 2016; Nelson et al., 2016). Hence, given the alignment between diets that are healthy and sustainable, and the costs of diets that are neither, the two are increasingly addressed together.
2) Shifts in the momentum for globalised trade towards more regional or local food systems. The last 5 years' geopolitical trends: (a) undermining the post-war architecture of international cooperation, (b) the rise of inward-looking and protectionist policies driven by increasing global inequality, including migration, have made a future of ever more liberal trade look uncertain – as barriers are erected distorting markets. Climate disruption and geopolitical instability can also undermine supply chain resilience, leading to a perceived need for more local sourcing from a security outlook. Social change (such as the belief that local food is somehow better) might also drive such a change. Other processes also consider the global to local dimension include the EU JRC's food safety foresight study,[8] and its scoping study the EC's Food[9] as well as the IPCC's Shared Socioeconomic pathways (e.g. SSP3 considers more regionalised economies) (O'Neill et al., 2017). The US and UK governments publish security-facing 'Global Strategic Trends' reports; the most recent editions both utilise scenarios which consider scenarios of radical change to the international architecture of trade and cooperation (Council, 2017; Defence, 2018). Other reports have highlighted the balance of risks, benefits and costs of trade, including the UK's climate change risk assessment (Challinor and Adger, 2016) and the EU JRC's 2030 foresight report on food.[10]

These two key axes set out four plausible, alternative, futures for food systems, each of which has different implications for what the future food system may be like: what food is grown, where it is grown, how it is grown and how is it used? (Figure 2)

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6 http://institut.inra.fr/en/Objectives/Informing-public-policy/Foresight/All-the-news/Agrimonde-Terra-foresight-study
7 https://ec.europa.eu/jrc/sites/jrcsh/files/jrc-study-tomorrow-healthly-society.pdf
8 https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/delivering-eu-food-safety-and-nutrition-2050-future-challenges-and-policy-preparedness
9 https://ec.europa.eu/food/sites/food/files/safety/docs/final_report_scoping_study_en.pdf
10 http://publications.jrc.ec.europa.eu/repository/bitstream/JRC94867/lbna27252enn.pdf

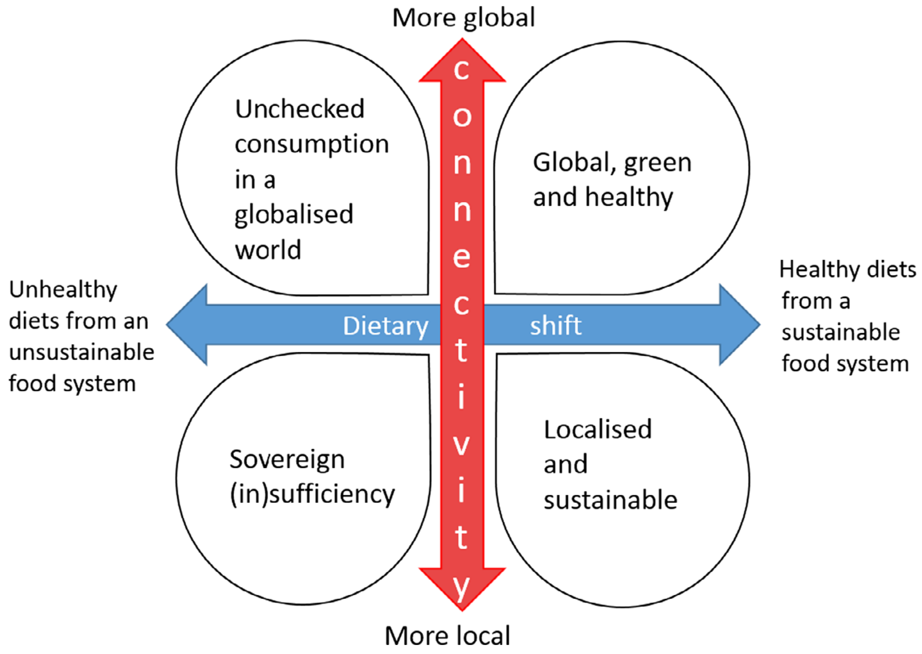

Figure 2: Four plausible, alternative, futures for food systems, based on axes of global-local connectivity, and degree of dietary shifts

Scenario 1: Unchecked consumption in a globalised world

This is the 'business as usual future'. More people on the planet, demanding more processed food based on a small handful of globally traded commodity crops, and more livestock consumption made possible from intensive feed production. The downward pressure on prices, within this scenario's conventional business model, causes a concentration in few crops grown at scale in breadbasket regions, global homogenisation of diets and makes it economically rational to waste food and over-consume calorie-dense products. This drives obesity and ill-health. In a world where meeting demand is the primary driver, 'sustainable intensification' is the mantra, and long supply chains the norm. Given intensive and efficient farming at large scales, and few crops and demand growth, overall emissions increase, driving climate change. This impacts on yields in many places, and, at the same time, increases land competition – as more land is required for negative emissions technologies (such as afforestation) to mitigate climate change. So ever greater yields are sought from the same area of crop-land, with high-tech, superintensive cropping systems, intensive livestock production (with lots of concentrated feed). To intensify and to build climate resilience, requires the broad adoption of biotechnology as well. Smallholder agriculture is increasingly amalgamated into larger land areas to provide yields and allow interconnection to global markets.

Scenario 2: Sovereign (in)sufficiency

This is a world in which nations look more locally or even inwards. Sovereign states have 'taken back control' from global markets and regained the 'sovereignty' they sacrificed to the 'the single worst trade deal' ever negotiated,[11] brokered within the international architecture of cooperation (the UN, WTO and other bodies), as well as multinational corporations. The ingrained notion that food should be cheaper from the dividend for protectionist policies, and the lack of political or social desire for a 'nanny state' telling people what to eat, shapes the way the system works. With a greater need for self-sufficiency, and a loss of agricultural efficiency that comes from comparative advantage and global trade networks, there is no scope for meeting demand from dietary breadth – so countries base diets on the handful of commodity crops in which they can specialise. These restricted crops are processed into food that can be consumed with pleasure, without regard to nutrition. Agriculture is super-intensive, but with little international cooperation there is no drive for land-based mitigation so the agricultural footprint expands, and farming becomes more intensive, more extensive and drives more

[11] Donald Trump, 22 May 2018 https://www.cfr.org/blog/trumps-china-deal-worst-ever

climate change. Nation states that differ in their endowments (land, water, soils, climate) and needs (population) become increasingly unequal. Endowment-poor, but highly populated, countries increasingly project power and grab land; endowment-poor nations with low population size struggle, and human migration increases. Both these undermine the national security of endowment-rich countries.

Scenario 3: Global, green and healthy

This is a world in which globalised cooperation works, and supply chains are long (and climate agreements are cooperatively ratcheted-up). Commodity-crop agriculture remains the predominant mode of agriculture at scale, with nutrition added through biofortification during the processing that adds other pleasurable attributes technologically but with fewer calories than the added sugar and fats in the scenarios above. Governments promote preventative healthcare, so people eat less and this reduces land-use pressure, and because climate mitigation happens more aggressively there are fewer climate impacts and less need for the extensive deployment of land-based negative emissions technologies, further easing the pressure on land. Intensification is significant as land remains limited, but not to the extent of the scenarios above, because government incentivises lower waste (partly through shifting subsidies making food pricier, partly through waste taxes and food-carbon taxes). The shifting subsidies, and changing social norms, result in small-scale but intensive horticulture (including lots of urban and vertical farming) for high-value, nutritious crops, grown in the urban environment and periurban fringe. Large-scale horticulture is increasingly adopted by technologically advanced, arid, states – where pest pressure is low and there are technological solutions to provide water (desalination, 'smart' irrigation).

Scenario 4: Localised and sustainable

This final scenario presents more of a world of circular food systems, diversified to provide healthy diets in more isolated regional food systems. Agriculture is more locally diverse, with more complex rotations, with mixed farming for nutrient cycling (including waste streams for local livestock and aquaculture). Because this system is more localised, the advantages of global competition maximising comparative advantage mean that the food system has to have efficiency built in, rather than a focus on increasing only agricultural efficiency. Agriculture policy is driven by nutritional needs not economic growth considerations. Health costs are avoided, through emphasis on 'preventative healthcare', and, along with circularity, agriculture is more diversified and landscapes more disparate. Food prices reflect the resources required to grow them, so environmental externalities are internalised. Because agriculture is more diverse, but food is less abundant, the value added by processing is relatively expensive, so people increasingly shift towards home preparation of food. The increased efficiency of the food system (people fed healthily per hectare) reduces food system emissions, globally mitigating climate risks. As with Scenario 2, more localised systems will exacerbate between-country inequality, which may lead to aggressive land-grabbing, or mergers of countries into larger local blocks (creating regionalised food systems). Additionally, food systems reflect more local climates/soil/water conditions, creating both greater seasonality of diets, and local specificity built on locally adapted produce.

Conclusions

The growing consensus that the food system is unsustainable in multiple dimensions has significant implications. As costs escalate, and as the world changes, it is likely that change will be forced on the system if it is not dynamic enough. As an example of the scale of change, at the moment, the world grows about 2.5 times more cereals than it would need to if everyone ate according to the USA's dietary guidelines (Bahadur et al., 2018), and about 20% of the fruit and vegetables that would be needed. The 'planetary health diet' (Willett et al., 2019) from the EAT–Lancet commission also highlights the gap between where we are going, our current trajectory and what is needed to make food systems deliver health and sustainability.

The current food system was designed around principles of consumption growth underlain by productivity growth, leading to economic growth facilitated by global market access. All these factors served a real purpose at the time. Now we need to start developing a food system not based on agricultural productivity, but based on the productivity of the food system: per unit input, how many people can be fed healthily and sustainably? (Benton and Bailey, 2019).

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Abbreviations

FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
SDG	sustainable development goal
WEF	World Economic Forum